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CONVAIR DIVISION OF GENERAL DYNAMICS CORPORATION

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CONVAIR - ARMA BENCH

TEST COMPATIBILITY

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PROGRAM

SEP 30 1959

REPORT NO. 78 2124-1

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REPORT_	7B 2124-1
PAGE	<u>i</u>
11 Aug	ust 1959

TABLE OF CONTENTS

PARAGRAPH	TOPIC	PAGE NUMBER
1.0	INTRODUCTION	1
2.0	SECTION I - SUMMARY OF ARMA AIG AUTOPILOT CO	
	TESTS	•
2.1	OBJECTIVES	
2.2	COMPLUSIONS	
2.3	TEST SPECIMENS	
2.4	TEST PROCEDURES	
2.4.1.	INITIAL INSTALLATION	
2.4.2	INITIAL TESTING	3
2.4.3	DETAILED TESTING	
2.5	TEST RESULTS	
2.5.1	INITIAL TEST RESULTS	
2.5.2	DETAILED TEST RECULTS	6
2.6	REFERENCES	
3.0	SECTION II - ELECTRICAL SYSTEM COMPATIBILIT	y test results 14
3.1	INTRODUCTION	14
3.2.0	OBJECTIVES	
3.2.1	LOAD ANALYSIS	
3.2.2	HARMONIC ANALYSIS	
3.2.3	TRANSFER CHARACTERISTICS	14
3.3.0	CONCLUSIONS	
3.3.1	LOAD ANALYSIS	
3.3.2	HARMONIC ANALYSIS	14
3.3.3	TRANSFER CHARACTERISTICS	14
3.4	RECOMMENDATIONS	14
3.5	DESCRIPTION OF SPECIMENS	14
3.6	TEST PROJEDURE	16
3.6.1	GENERAL PROCEDURE	16
3.6.2	SPECIFIC PROCEDURE	
3.7	TEST RESULTS	
3.7.1	LOAD ANALYSIS	19
3.7.2	HARMONIC ANALYSIS	19
3.7.3	POWER TRANSFER	20
4.0	SECTION III - ILLUSTRATIONS	
4.1	LIST OF ILLUSTRATIONS	
4.4	FIGURES 1 THROUGH 43	

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ASTRONAUTICS

UNCLASSIFIED

18 1 20 24-1

11 August 1959

1.0 INTRODUCTION:

With reference to STL Document GM437-335 Engineering Bench Compatibility Test Plan and Arma Document DMG 4562 Laboratory Compatibility Program, STL requested that engineering bench compatibility tests between Convair Autopilot and Arma Inertial Guidance System Components be conducted. Accordingly, the Servo-Mechanisms Group requested that those tests be performed in the Systems Test Laboratory, as specified in Convair Report AZM-27-073, dated 27 October 1958.

The purpose of the bench tests was to determine any system isomepatibilities as early in the D/AIG program as possible. Primarily, these tests were made to determine the nature and cause of any interface problems that might exist between the available Convair and Arma equipment. Overall missile system compatibility is to be determined during the 300 Tests.

The beach tests were divided into two categories; measurements to determine that interface signal requirements were met, and measurements to determine if the systems component power requirements were compatible with the airborne power supply.

This report is therefore divided in two sections. The first section contains Quidance-Autopilet signal compatibility information, while the second section contains the data on the compatibility of the guidance system with the airborn power supply. The first part of this report is based primarily on information supplied by Arma, and on information contained in reports issued by the Servo-Mechanisms Group as listed under reference.

2.0 SECTION I: Summery of Arma/AIG Autopilot Compatibility Tests.

2.1 ONJECTI SE

Determine -

- 2.1.1 Signal domestibility between Convair AEC Autopilot and Arma MCS.
- 2.1:2 Operational characteristics of the guidance system on the air borne power supply.
- 2.1.3 Operational characteristics of the guidance system during power changeover.

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PAGE 2

13 August 1959

2.2 CONCLUSIONS:

- 2.2.1 No serious incompatibilities were detected between the Convair Autopilot system and the Arma MGS during these tests.
- 2.2.2 The guidance system performed correctly on both ground and airborne power supplies over a wide range of power system load conditions.
- 2.2.3 The operational status of the ARG Autopilot was recovered within a fraction of a second after power changeover, while the Arma equipment was fully operational within five seconds in all tests run.

2.3 TEST SPECIMENS:

- 2.3.1 Convair D/AIG Autopilot Components
 Gyro Package
 Servo Amplifier Package
 Digital Programmer Package
- 2.3.2 Convair special test equipment Control Maneuvers Servo Table Package Control Units
- 2.3.3 Convair Power Supply Components
 Inet-Palmer ground power unit
 Airborne Inverter power unit

For a more detailed description of these units, refer to the Electrical Section of this report.

- 2.3.4 Arma Lot II Missile Guidance System
 Computer
 Instrial Platform
 Analog Signal Converter
 Digital Signal Converter
 Control Central
- 2.3.5 Arms Special Test Equipment ET-1 MGS Test Racks Computer Test Kit Simulated Break Away Fanel

2.4 TEST PROCEDURES:

2.4.1 Initial Installation

A walled in, limited access area at Columns J, K-1, Fldg. 5 was created for equipment security, 25 January 1959. The Arma Yest hardware was then installed and connected. Power 11ses, control boxes and outlets were installed, furnishing as necessary:

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NOTE 3

11 August 1959

2.4 TEST PROCEDURES: (Continued)

2.4.1 Initial Installation (Continued)

440 volts, 60 cps, 3 phase

11.7 volts, 400 cps, 3 phase

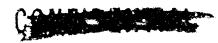
117 volts, 60 cps, 1 phase

28 volts, DC

Forced air, dry ice equipment scelers were designed and built for Arma equipment, as were a New minor pieces of special test equipment. The required test instruments were obtained and the area was checked out and operational by 9 February 1959. See Figures 1 through 5.

- 2.4.2 Initial Arms/AID Core Canister Convetibility Tests -
- 2.4.2.1 On 9 February 1959 the first prototype ANG gyro canister was tested for compatibility with the Arma MGS. The object of this test was to determine if any discrepancies existed when pitch and yaw steering rignals were supplied to the gyro canister.
- 2.4.2.2 Ir the first test pitch steering signals from the pitch einbal cyachro of the Arma Inertial Platf 's were supplied to the pitch guidance input of the torquer amplifier in the gyro canister. Signals renging from +5.0 to -5.0 velts in 1 volt ingrements were used as inputs. The parameters recorded on a Sanborn recorder were as follows: Input Signal, Pitch Cyro Output. Pitch Amplifies Output and Pitch Torque Current. At such voltage input level, the pitch guidance was disabled through an electronic switch in the gyro conister and the gyre was electrically mulied. The mulling leop was them opened and the pitch guidance was anabled, allowing the signal to torque the gyre. The resulting rump outputs and torquing surrent were recorded at that time.
- 2.4.2.3 The second test was to apply you steering signals from the computer to the you guidance input of the torque emplifier in the gyro sanister. The inputs ranged from +) volts to -3 volts in 0.5 volt increments. The parameters recorded on the Sanbern recorder were as follows: Input Signal, Yaw Gyro Output, Yaw Signal Amplifier Output, and Yaw Torque Current. As in the case of the pitch channel, the yaw guidance was disabled through the electronic switch, and the gyro was electrically mulled.

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2.4 TEST PROCEDURES: (Continued)

2.4.2.3 (Continued)

The nulling loop was then opened and the yew guidance was emabled, allowing the signal to torque the gyro.

- 2.4.2.4 In phase and quadrature components of Arma pitch and yaw steering signals were measured.
- 2.4.2.5 Arms-Convair guidance interface impedances were investigated.
- 2.4.2.6 The efficiencies of the termor amplifier guidance enable switches were evaluated by noting their attenuation of the guidance input in the gisable mode.
- 2.4.3.0 After these initial checks, the detailed testing program was undertaken, and completed by 8 May 1959. The following areas were investigated:
- 2.4.3.1 Pitch and Taw Steering
 - a) Open Autopilot gyre loop
 - b) Closed Autopilot gyro losp
 - c) Closed Autopilot gove loop about a flight maneuvers serve table.
- 2.4.3.2 The pitch and yaw stearing tests were conducted to determine the compatibility of the Arms system with the autopilet gyre consister as well as to compare gyre terquing races measured three separate ways; open and closed gyre loop, and closed loop through the maneuvers tolder.

Autopilot gwro paska, e servo loop parameters were also investigated.

- 2.4.3.3 Fitch gyro drift due to pitch steering null signal was investigated.
- 2.4.3.4 You gyr a drift due to you steering null signal was investigated.
- 2.4.3.5 Effect of yew steering signal ripple on gyro suplifier entput was money ed.

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2.4 TEST PROCEDURES: (Continued)

- 2.4.3.6 A normal Lot B 1-G problem yaw steering signal was fed from the Arma Computer to the Autopilot while the computer cutoff signals were sent to the programmer. The tests were run on ground power and repeated using the airborne power supply. The autopilot was operated closed loop using an external nulling amplifier.
- 2.4.3.7 Simulated Lot C 1-G Test closed loop. Lot C is a more advanced form of the Arma MCS. A simulated Lot C yaw steering profile was generated by manually satting the yaw steering signal levels in the proper time sequence with the Arma computer test kit. The tests conducted with the simulated Lot C sequence profile were the same as for the normal 1-G profile with the exception that cut-off signals were not available.
- 2.4.3.8 Sensitivity of discrete signal circuits to over and under supply voltages was measured.
- 2.4.3.9 The effect of switching on and off the simulated loads on the guidance system power supply was investigated. Arma MGS operation at the specification limits of power supply amplitude and frequency was measured.
- 2.4.3.10 Effects of power changeover, from ground to airborne, on the guidance system was measured.

2.5 TEST RECULTS:

- 2.5.1.0 Initial Arma/AIG Gyro Canister Compatibility Tests.
- 2.5.1.1 The results of the pitch steering tests may be seen in Figure 6 where input voltage is plotted versus Autopilot gyro output, amplified gyro output, and torque current. This data appeared to be consistent with what was expected.
- 2.5.1.2 Figure 7 shows the results of the yaw steering tests. The null voltage input was 60mv total with negligible phase rensitive component. The recorded gyro drift at this time was approximately 0.005 volts/second or 25 degrees/hour using the nominal gyro sensitivity of 0.7 volts/degree.
- 2.5.1.3 The in-phase and quadrature components of Arma MGS yaw and pitch output steering signals were measured and recorded by Arma at this time also. Their results are shown in Figures 8, 9, 10 and 11.

CONVAIR

ASTRONAUTICS

7B 2124-1

PAGE 6

11 August 1959

2.5 TEST RESULTS: (Continued)

2.5.1.4 The tests of Figures 6 and 7 were made by adjusting the Arma outputs to the desired torquer amplifier input voltage levels. This cancelled any loading effects on the Arma equipment which may have existed. However, Arma supplied the following information on its pitch and yaw source impedances:

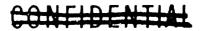
Pitch 370 ± 20% + j250±20% ohms Yaw 6000 ohms

These impedances drive the pitch and yaw guidance input circuits of the gyro torquer amplifiers, each of which offers a load of 100,000 ohms with guidance disabled and about 190,000 ohms with guidance enabled ensuring a good impedance match with Arma.

- 2.5.1.5 The enable disable guidance switches appeared to function efficiently. With 3 volts RMS steering signal applied to the guidance input, and with the switch in the disable condition, .00417 volts per second appeared at the amplifier output. Using a sensitivity of 4.5 volts/degree this is equivalent to a drift rate of 3.34 degrees/hour.
- 2.5.2 Results of Main Testing Frogram -
- 2.5.2.1 Pitch and yaw steering

The pitch steering tests were similar to those run in the initial checks, with signals ranging from null to ±4 volts used as inputs. All testing was done on both ground and airborne power. With the Autopilot gyro loop open, the ramp output from the signal amplifier was recorded at each voltage level after initially nulling the gyro and disabling the guidance input. Simultaneously, the nulling loop was opened and the guidance was enabled allowing the gyro to slew to its stop.

For the second test, the gyro nulling loop was left closed, and the guidance was enabled, while the gyro displacement was measured at the nulling amplifier output for each steering input level. The third test was to close the loop about the control maneuvers servo table and monitor the table rate at each input level. Sample recordings of these tests can be seen in Figures 12 and 13. With the servo loop closed, the rate gyro output was recorded to determine whether any inconsistencies existed in table rate.



CONVAIR

ASTRONAUTICS

REPORT 7B 2124-1

PAGE_____7

11 August 1959

2.5 TEST RESULTS: (Continued)

2.5.2.1 Pitch and yaw steering (Continued)

The yaw steering tests were run in a similar manner, with signals ranging from null to ±3 volts used as inputs. The open loop tests were performed as before by applying the yaw steering signals to the guidance input after which the nulling loop was opened and the guidance enabled allowing the gyro to slew to its stop. The ramp output from the gyro signal amplifier was recorded as shown in Figure 14. The same test was repeated with the nulling loop closed and the output of the nulling amplifier recorded, also shown in Figure 14.

2.5.2.2 Autopilot Gyro Package Torquing Rates and Parameters -

Figure 16 is a block diagram of a floated rate integrating gyro and its associated circuitry. The blocks inside the dotted lines represent the components of a floated rate gyro, while those outside represent needed circuitry for open or closed loop operation. Open loop torquing is accomplished with S1 and S2 open, and with the signal applied to the guidance input. Closed servo table loop torquing is accomplished with S1 closed and S2 open. Closed gyro loop torquing is accomplished with switch S1 open and switch S2 closed.

The gyro open loop torquing rate may be defined by

$$\frac{6\Theta_0}{E_1} = \frac{\Theta_0}{E_1} = \frac{K_t S_t}{C} \frac{\text{deg/sec}}{\text{volt}}$$

Where Kt = torquer amplifier gain in volts/volt

St = torque generator transfer function in volts/deg.

C = viscous damping torque of the gyro in dynes - cm/deg/sec

The open loop torquing rate is calculated from the voltage ramp output of the signal amplifier using the displacement sensitivity which is calibrated to ±5.5%.

Closing the loop about a servo table on which the gyro package is mounted, the torquing rate becomes

$$\frac{800}{E_1} = \frac{60}{E_1} = \frac{K_t}{H} \frac{S_t}{H}$$

where H is the gyro angular momentum.

CONVAIR

ASTRONAUTICS

REPORT 7P 2124-1

PAGE 8

11 August 1953

2.5 TEST RESULTS: (Continued)

2.5.2.2 (Continued)

It can be seen that the torquing rates obtained using these two methods of measurement could differ considerably especially if the damping should vary some percentage over a specified temperature range. Figure 17 does show, however, a fairly good correspondance between open and closed serve loop torquing rates.

The third method tried was to close the loop about the gyro itself, torque the gyro electrically with the Arma steering signals, and record the output of the nulling amplifier for each input level. Since the input summing resistors at the input to the torquer amplifier are in the ratio of 1.21 to 1, the voltage $\mathbb{E}_{\mathbb{R}}$ should be 1.21 X $\mathbb{E}_{\mathbb{I}}$ at any input level. This is verified in Figure 17.

The predominate time constant of the Autopilot gyro nulling loop as computed to be 0.5 second. This seems to agree with the time constant recorded in the simulated Lot C 1-G Test shown in Figure 8. In this test the gyro loop was closed and the nulling amplifiar output was recorded, showing a nulling loop time constant of about 0.5 seconds. If necessary, the loop gain could probably be increased sufficiently to lower the time constant, as the loop possesses an ample gain margin.

Summarizing, the gyro nulling loop had a computed natural frequency of 3.5 cps. a desping ratio of 5.62, and a time constant of 0.5 seconds. All these parameters are a functine of loop gain which can be controlled by adjusting the gain of the nulling amplifier.

~.5.2.3 The pitch steering signal was nulled by pinning the inertial platform pitch gimbal with a zero pin.

The effect of the Arma pitch steering null signal on the apparent Automilot gyro drift was then recorded as shown in Figure 18. This hull drift was recorded for six minutes. The drift in degrees per hour was calculated using the pitch displacement sensitivity which was calibrated to 3.5 volts/degree. This calculated drift is shown as follows:

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ASTRONAUTICS

78 2124-1 PAGE 9 11 August 1959

2.5 TEST RESULT: (Continued)

2.5.23 (Continued)

Drift at the end of six minutes

0.9 volts

Drift per hour

9 volts/hour

Drift in degrees/hour

9 volts/hour = 2.57 deg/hr.

3.5 volts/deg.

- 2.5.2.4 The Arma yaw steering signal was nulled by use of the computer test kit in the "zero subtract" position. The effect of the yaw steering null signal on the apparent Autopilet gyro drift is shown in Figure 19. The gyro drift was recorded for three minutes in each direction by reversing the Arma computer reference voltages phase. In either direction the drift appeared to be low, 2.27 deg/hr. to 3.46 deg/hr., both within tolerance. The difference between these two drift rates is 1.19 deg/hr. which is the true gyro drift rate caused by the imperfect null signal.
- 2...2.5 The 2 cps ripple on the yaw output of the Arma computer did appear at the output of the nulling amplifier as a 0.1 volt peak-peak signal. The amplitude of the 2 cps ripple is dependent on the steering input signal level. As shown in Figures 14 and 15, the input signal level for 1.1 volts peak-peak was about 3 volts RMS. To determine the effect of the 2 ops ripple on the entire Autopilot system including the sustainer and vermier engines, the resulting 2 cps ripple was recorded at the output of the yaw signal amplifier. See Figure 20. With a 3 volts RMS input signal, the peak-peak voltage appearing at the output of the signal amplifier was 0.2 volts. The sustainer and vernier engine deflection for a peak-peak input of 0.2 volts can be calculated as follows: the end to end sustainer pitch and yaw displacement gain is 1.85 deg/deg. The yew versier displacement gain is 15.3 deg/deg. A one degree displacement input produces 3.5 volts signal amplifier out. It follows that the sustainer displacement sensitivity is

1.85 wee/deg. = 0.53 deg/volt



CONVAIR

ASTRONAUTICS

REPORT 7B 2124-1
PAGE 10

11 August 1959

2.5 TEST RESULTS: (Continued)

2.5.2.5 Therefore a 0.2 volt peak-peak signal amplifier output produces a sustainer deflection of

 $0.53 \times 0.2 = 0.106$ degrees peak-peak at 2 cps.

The vernier displacement sensitivity is

$$\frac{15.3}{3.5}$$
 = 4.37 dag/volt.

Thus a 0.2 volt peak-peak signal amplifier output produces a vernier deflection of

 $4.37 \times 0.2 = 0.874$ degrees peak-peak at 2 cps.

From the above calculations, it appears that these small engine deflections will not be detrimental to the autopilot control system. The calculated sustainer deflection should be within the dead zone of the engine serve system.

The third test performed with yaw steering input signals was to close the loop about the control maneuvers serve table. This test is shown in Figure 15 where the rate gyro output shows a 0.04 volt peak to peak 2 cps oscillation. This is equivalent to 0.2 deg/sec. peak-peak modulation upon the table rate of 1.24 deg/sec.

- 2.5.2.6 The normal Lot B 1-G yaw steering profile using airborne power is shown in Figure 21. This test was done with the Autopilot gyro nulling loop closed and the output of the nulling amplifier recorded. No unusual transients appeared on the recording and the output appeared normal. Figure 10 shows another recording taken on airborne power.
- 2.5.2.7 The simulated Lot C 1-G test is shown in Figure 22. In this test the gyro loop was closed and the mulling amplifier output was recorded.



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ASTRONAUTICS

REPORT_	7B 2124-1
PAGE.	11
11 Aug	ust 1959

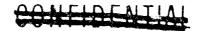
2.5 TEST RESULTS: (Continued)

- 2.5.2.8 On 12 March 1959, the Arma MGS and Conveir Autopilot were run as a system. One G problems were run with the computer cut-off signals going to the programmer. The DC power supply was adjusted for nominal, under and over voltage levels. The performance of the MGS-Autopilot discretes circuitry was normal under all conditions.
- 2.5.2.9 The entire simulated load was switched on and off to simulate an extreme airborne power profile. No significant variations appeared in the recorded outputs of either Arma or Convair guidance components. The Arma MIS operation was normal at the specification limits of power supply amplitude and frequency.
- 2.5.2.10 Power Transfer Tests were made to determine the effect on the operational status of the MGS and Autopilot components. Phase switch-over times were unequal, and transients lasted as long as thirty milliseconds. However, total separation from the ground supply was always achieved before the airborne inverter was switched in.

The servo package recovered operational status within several milliseconds and therefore posed no problems.

Changeover tests were performed with the programmer at zero ready to receive a launch command. At power changeover the programmer power supply voltage decreased which resulted in programmer logic commanding a satisfactory reset to zero as the voltages returned to normal values. No undesirable voltage transients were noted in critical programmer outputs.

The effects of power changaover on the gyro package are shown in Figures 23, 24 and 25. There appear to be no problem areas except for a 0.3 volt transient spike lasting for 0.1 second appearing at the output of the signal amplifier. This should have a negligible effect on system operation.



CONVAIR

ASTRONAUTICS

REPORT 7B 2124-1

PAGE____12

11 August 1959

2.5 TEST RESULTS: (Continued)

2.5.2.10 (Continued)

The first area of investigation on the 4rma equipment was the effect on platform alignment. As the Lystem power was switched from ground to airborne, the steering resolver and pendulum outputs were recorded, as in Figures 26, 27 and 26. Any change in resolver or pendulum outputs would indicate gimbal motion. There was no change in pendulum output as a result of power changeover. A 2.5 millivolt change in roll resolver output was recorded indicating a twenty second error. As the resolver output is directly proportional to line voltage, a major factor in the resolver output change is the difference between the voltage levels of the ground and airborne supplies. The voltage difference was about 1% at the time of this measurement.

Platform azimuth alignment was monitored optically using a Watts autocollimator to sight on the platform porro prism. The angular offset of the platform in azimuth due to power transfer was less than five seconds for repeated runs.

The recovery of azimuth alignment from an offset was normally observed to be accomplished within two or three seconds as a result of the ET-1 Equipment Gyro Torquing Amplifiers. At no time did recovery exceed seven seconds. On the basis of these figures, Arma states that the platform will have fully recovered from any offset due to power transfer prior to launch.

The power transfer transient was reflected in the platform and computer power supplies. There was no significant increase in ripple or noise on the DC voltages after transfer. Observed control and power supply voltages of the Arma equipment are tabulated in Figure 30 to give qualitative definition to the supply variations after changeover.

The Arma MGS serve amplifier output showed a ripple at the difference frequency of the two supplies. The Figure 29. Maximum ripple was about 1 volt peak to peak to peak to take voltage was within specifications. Serve response was normal judging by the recovery time from a step input. It is presumed that this "hum" pickup will not be present in the missile once the unbilical is detached.

ASTRONAUTICS

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2.5 TEST RESULTS: (Continued)

2.5.2.10 (Continued)

Computer operation was normal on airporne power when reset after transfer. Figure 30 offers a qualitative indication of the transfer effects on the computer operating voltages.

2.6 REFERENCES:

Report ES-59-SM-322 dated 18 March 1959, Results of Initial Arma/AIG Gyro Canister Compatibility Telus.

Report ES-59-SM-384 dated 25 May 1959, Summary of Arma/AIG Autopilot Compatibility Tests.

Engineering Work Book No. 7404.

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3.0 SECTION II: Electrical System Compatibility Test Results.

3.1.0 INTRODUCTION.

The purpose of this phase of testing was to evaluate the electrical compatibility of the D/ATO power system of the Arma MDE - ARO Autopilet guidance system.

- 3.2.0 OBJECTIVES:
- 3.2.1 Obtain a load analyst for the D/ARD Missile Power System.
- 3.2.2 Obtain a harmonic analysis of the sirborne power system.
- 3.2.3 Trains power system characteristics prior to transfer, during sfer, and after transfer.
- 3.3.0 CONCLUSIONS:
- 3.3.1 The nominal lead on the D/AM Missile Power System was 1620 watte. The Arms Inertial Guidance System senstituted three-fourths of the hominal load.
- 3.3.2 The barmonic analysis of the airborne inverter indicates that the voltage harmonic content from the second to twentieth harmonic was approximately 0.033 of the fundamental.
- 3.3.3 Recordings taken of power system transfer indicate that the position transfer time (power interruption) exceeds the maximum specified of 15 milliseconds.

Arms total current transients at transfer are not excessive in magnitude and are generally less than 2.5 milliseconds in duration.

3-4.0 RECOMMENDATION:

It is recommended that further testing of the changeover switch he condusted on the systems level.

3.5.0 DESCRIPTION OF SPECIMENS:

There were few major electrical components used in this tests.

3.5.1 Power Changeover Switch -

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15

11 August 1959

3.5.1 Power Changeover Switch - (Continued)

Kinetics Corp.

M-160-2

Serial No. 002

CVAC 27-06106-3

3.5.2 Airborne A.C. Power-

Inverter - Bendix, Red Bank Division 32B77-5-B

Serial Number R-14

Output: 115/200 volts AC 400 cycles,

3000VA, 3 Phase, 0.8 pf.

Input: 28 volts DC 185 amps.

3.5.3 Ground A.C. Power

Variable Frequency Motor - Generator

Inet-Palmer Division of Leach Corp.

Model A1264

Serial Number 3673-1

Convair Specification No. 7-06205

Input

Output

Volue: 390/510

120/208

freq:

58/62 cyc.

380/420 cyc.

Phase:

3

3

Amps:

30.5

41.6

P.F.

0.8

0.95 lead to 0.75 lag

XVA:

15

3.5.4 Ground-Airborns D.C. Power

Stavolt D.C. Fower Supply

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7B 2124-1 16 PAGE.... 11 August 1959

3.5.4 Ground-Airborne D.C. Power - (Continued)

Mc Colpin - Christis Corp.

431-400K4

Serial Number K-458

Output: 400 amps

25-29 volts DC

Input: 440w 3 Phase 600yc. 30 Amps.

3.5.5 D. C. Power to Arma Ground Equipment -

Rectifier, Metallic

Christie Electric Corp.

MH32-100 K4

Serial Number K-1804

Output: 100 amp. 24-32v DC

Input: 460 volts 60 cyc. 3 Phase

3.6.0 TEST PROCEDURE:

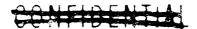
3.6.1 General Procedure -

3.6.1.1The electrical power system used followed the schematic Drawing (SX 545-7-159) furnished by the Electrical Design Group, Dept, 545-7. Additions and changes were incorporated to facilitate instrumentation and system grounding. Basically, the system conforms to the power system diagram given in Figure 31. The solid lines indicate flow of power whereas, the dashed lines indicate measurement or instrumentation coverage.

The system was so arranged as to provide Arma ground control equipment with AC ground power at all times.

The electrical wiring was of the thres-phase, four wire, configuration. Two No. C cables were connected between each package load and inverter to *imulate missile grounding. The common neutral (fourth wire) between airborne and ground AC power supplies was separated during airborns compatibility testing.

ীৰ প্ৰথমেন্ত্ৰৰ হোৱাৰ বিভাগৰ কৰিব বাংলাৰ বিষয়ে আৰু আৰু প্ৰাৰম্ভাৰ বাংলা হৈছিল। মাধ্য বাংলা বাংলা বিষয়ে আৰু আৰু একং বিচাৰ হৈ (3) Alter Bar la la marage en elle elle atte t , mights in lenk matcher to an unauthor bet beisse is beish billed (k. a.e.



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ASTRONAUTICS

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11 August 1959

3.6.1.1 (Continued)

The test inverter and changeover switch had were used in several other tests by Systems and Components Test Laceratories.

3.6.1.2 The system loads were operated in the ready made during electrical power tests. The airborne loads consisted of the following:

3.6.1.2.1 Arma MCS

- a, Flatform Package
- b, Computer Package
- a, Control Package
- d, Analogue Signal Converter
- e, Digital Signal Converter

3.6.1.2.2 AE Automiliati

- a, Phase A transducer (simulated)
- b, Gyro Package
- o, Programmer Package
- d, Servo implifier Package
- e, Programmer and Serve Amplifter Monitoring Famels

3.6.1.2.3 Simulated Loads:

- a. Propellant Utilisation
- b, instrumentation (Model 3)

These similated loads were imped together and consisted of a transformer-rectifier resistive load and an inductive load.

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78 2124-1 PAGE 18 11 August 1959

3.6.2 Specific Procedure:

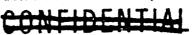
The load analysis and harmonic analysis measurements were taken at the analyser. Both analyses were performed on airborne inverter power with the external ground wire disconnected.

- 3.6.2.1 The load analysis was performed using a voltmeter, ammeter and wattmeter with associated current transformers. Pictures of the phase
 voltage and current waveferms were taken with a Type 2614 Dumont
 attachment and camera and a Type 53/54C Textronix Dual-Trace Plug-In
 Unit in a Type 545 Textronic Oscilloscope.
- 3.6.2.2 The harmonic analysis was performed using a Model 300A Hewlett-Packard Harmonic Analyser. The half band width selectivity was set at 145 cycles. Frequencies outside this bandwidth were attenuated by a minimum of 40th. The voltage harmonics were measured directly across the line and the current harmonics were measured across a 50 millivolt, 10 ampere shunt in the line.
- 3.6.2.3 Power changeovers (transfers) were performed with over, nominal, and under voltage outputs from the inverter. Recerdings were obtained on a Type 5-119 CEC oscillograph. Type 7-326 Calvanometers were used for the AC traces. These galvanometers have a frequency response flat to 3000 cycles. A Weston, Model 461 current transformer and CEC Linear Amplifier, Type 1-112-C were used to isolate and amplify the instrumentation signal of each line current. This instrumentation circuit gave erroneous indications of the line currents during transfer art was therefore revised for subsequent testing. The revised circuitry utilized a 7.5 ampare, 50 millivolt blant in each line and a Type 7-319 Galvanometer. This galvanometer has a frequency response flat to 300 cycles.

3.7.0 TEST RESULTS:

3.7.1 The load analysis data are given in Figure 32. The power factor was calculated from measured values of voltage, amperes, and watts. All values with the exception of watts, given in the total rows of the table are calculated on the basis of 115 volts. The system line voltages and inverter direct current and voltage are given at the right.

The loads were not steady because of heaters turning off and on in the Autopilot packages. Therefore two load analyses were run.



CONVAIR

ASTRONAUTICS

REPORT_ 7B 2124-1

PAGE 19 11 August 1959

3.? TEST RESULTS: (Continued)

- 3.7.1.1 A nominal value of system loading was 1620 watts. In comparing the loads of Run 1; Arma MGS comprised 73.5%, AIG Autopilot was 10.6% and the simulated load was 15.9% of the total load. The AIG Autopilot load had the greatest variance in phase current and power factor.
- 3.7.1.2 The waveforms of voltage and current are given in Figure 33. These pictures show the distortion in the waveforms and the phase angle between the phase voltage and current. The photograph on the right shows the waveforms with total system load on the airborne inverter. The photograph on the left shows the waveforms with the simulated load dropped from the total system load. The system load without the simulated load is given in the load analysis table.
- 3.7.1.3 The simulated load was used for nominal and extreme variations in loading on the power supply for power ystem compatibility testing.
- 3.7.2 The harmonic analysis data are given in Figure 34. The values of harmonic voltages given are from direct measurements. The values of harmonic currents given are calculated from the voltage drop measured across a 10 ampere, 50 millivolt shunt in each line. Here again the load on the system was not steady and two sets of data were taken.
- 3.7.2.1 The middle portion of the analysis table gives the harmonics in percent of the fundamental. The seventh and eleventh harmonics are the most prominent voltages, whereas the second, third, fourth, fifth, seventh, eleventh and fifteenth harmonics are the most prominent currents.
- 3.7.2.2 The harmonic content of the voltage is given at the bottom of the table. Interface requirements of AZM-27-075 call out that the RMS sum of the voltage harmonics from the second through the tenth shall be equal to or less than 4% of the fundamental. Also, the RMS sum of the harmonics from the second through the fortieth shall be equal to or less than 0.05 of the fundamental. The voltage harmonic content of the tested inverter clearly meets the first part of the specification. The harmonic content was only measured to the twentieth therefore a categorical statement about its harmonic content to the fortieth is impossible. Nevertheless, if the harmonic content to the twentieth is doubled the calculated R.M.S. content is 0.0495 of the fundamental. It is unlikely that the harmonic content from the twentieth through the fourtieth will be as great as the content from the second through the twentieth. Therefore it is assured that the harmonic content of the inverter meets the second part of the specification.



CONVAIR

ASTRONAUTICS

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3.7 TEST RESULTS: (Continued)

3.7.3 Power transfer recordings are given in Figures 35 through 43. The changeover switch used in this test was not of the type that will be on the D/AIG Series. A proper changeover switch was not procured for this test. The essential difference between the two switches consists of the number of switching circuits. The switch used in the test had three sets of three AC load switching circuits. A set consists of either three Phase A, Phase B or Phase C switches. The changeover switch that will be used on the D/AIG Series has three sets of five AC load switching circuits.

The changeover switch used did not have the required number of switching circuits. Therefore, the packages of each subsystem; Arma MCS, AIG Autopilot and Simulated were connected to a single switching circuit. The effect this had on the test is probably negligible. However, the exact time of transfer for each package would be different. Also, the transfer time sequence would cause a change in the time and magnitude of the total system transfer transient.

- 3.7.3.1 With the system loads as in the load analysis test, several power transfers were run. Typical recordings of these changeovers are given in Figures 35 and 36. These recordings are of total system load currents and voltages. These recordings show inconsistent transfer times. This characteristic was discussed with the Electrical Design Group. Upon investigation it was learned that the electrical system wiring was improper. Each set of load switching circuits had been connected together in order to instrument the total load current at transfer. Referring to the system diagram, Figure 31, the proper circuitry is to have the distribution coincide with the changeover switch. The proper changes were incorporated. The above mentioned recordings, Figures 35 and 36 are included here to show what the total system or each package saw for power transfer testing. When the changeover circuitry was properly revised, the Autopilot packages were no longer available for test.
- 3.7.3.2 In order to determine the electrical characteristics at transfer for the Arma MGS equipment, further power transfer testing was conducted. The AIG Autopilot load was lumped into the simulated load. Figure 37 is a recording of Arma voltage and current at transfer. It clearly shows the presence of high frequency transients. High frequency current transients are also apparent at the transfer command time. At this time the motor driven changeover switch begins to move.



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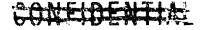
3.7 YEST RESULTS: (Continued)

- 3.7.3.3 The apparent DC displacement of the currents at break and male of transfer are spurious. To check on these spurious displacements, a step function was applied to the recorder circuit and it responded approximately at two cysles, dauped exponentially. The recorder current instrumentation circuit which caused the regricus displacement and its revision are discussed in Paragraph 3.5.2.3.
- 3.7.3.4 Figures 38 through 43 are records of Arma MGS electrical characteristics at transfer using the revised current instrumentation circuitry. The response of the Type 7-319 Calvanometer is down approximately seven percert at 400 species. These records show pragressively power transfers from external to internal and internal to external, with over, nominal, and under voltage on the inverter. The position transfer time is more clearly defined than was indicated by the high frequency response records. The position transfer time is definitely outside the maximum specified time of 15 milliseconds. Phase & current transfer time approaches 30 milliseconds.
- 3.7.3.5 These records also sorve to indicate the ourrent switching transients. The transients are somewhat variable because of their dependence upon the time displacement of the wellage cycle at switching and the mode or power factor of the load.

It may be observed that the voltages are small in magnitude before the completed operation of switching at make and break. A possible cause of this may be the construction of the switching contacts. The switches are of the sliding pin-socket type and their area of contact, or contact resistance will change with the time-position of the sliding contact.

3.8.0 BIBLIOGRAPHY:

Test date from which this report was prepared are recorded in Engineering Test Laboratories Data Motebook No. 7134.



CONVAIR

ASTRONAUTICS

REPORT 78 2124-1

PAGE 22

11 August 1959

4.0 SECTION III - ILLUSTRATIONS:

4.1 LIST OF ILLUSTRATIONS -

FIGURE NO.	TITLE	PAGE	NUMBER
J .	CONVAIR - ARMA COMPATIBILITY BENCH TEST AREA		23
2	ARMA EQUIPMENT GROUP		24
3	ARMA TEST GROUP		25
4	ELECTRICAL TEST GROUP	• • • •	26
5	AIRBORNE POWER GROUP		27
6	INITIAL PITCH STEERING TESTS		23
7	INITIAL YAW STEERING TESTS		29
8	ARMA PITCH RESOLVER OUTPUT COMPONENTS		30
9	ARMA YAW COMPUTER OUTPUT COMPONENTS		31
10	ARMA PITCH RESOLVER OUTPUT PERCENTAGE COMPONENTS		32
11	ARMA YAW COMPUTER OUTPUT PERCENTAGE COMPONENTS		33
12	PITCH CLOSED LOOP TORQUING TEST		34
13	PITCH GYRO AMPLIFTER TEST		35
14	YAW CYRO AMPLIFIER TEST		36
15	YAW CLOSED LOOP TORQUING TEST		37
16	BLOCK DIAGRAM OF RATE GYRO		38
17	TABLE OF GYRO PACKAGE TEST RESULTS		39
18	PITCH GYRO DRIFT RATE TEST		40
19	YAW GYRO DRIFT RATE TEST		41
20	YAW SIGNALS ON AIRBORNE POWER		42
21	LOT B 1-G YAW STEERING PROFILE		43
22	LOT C1-G YAW STEERING PROFILE		44
23	YAW CLOSED LOOP POWER CHANGEOVER TESTS		45
24	YAW OPEN LOOP POWER CHANGEOVER TEST		45
25	YAW GUIDANCE ENABLED CHANGEOVER TEST		47
26	ARMA INERTIAL FLATFORM RESOLVER OUTPUTS		48
27	ARMA INERTIAL PLATFORM PENDULUM OUTPUTS		49
28	ARMA INERTIAL PLATFORM PENDULUM OUTPUTS		50
29	ARMA SERVO AMPLIFIER OUTPUTS		51
3 0	COMPUTER AND CONTROL VOLTAGES		52
31	POWER SYSTEM DIAGRAM		53
32	LOAD ANALYSIS TABLE		54
33	PHASE VOLTAGE AND CURRENT WAVEFURNS		55
34	HARMONIC ANALYSIS TABLE		56
35	TOTAL SISTEM POWER TRANSFER		57
36 22	TOTAL SYSTEM POWER TRANSFER		58
37	ARMA PUNER TRANSPER (HIGH FREQUENCY CURRENT TRANSTENTS).		59
38	ARMA POWER TRANSITER (EXTERNAL-INTERNAL, CYFR VOLTAGE)		6 0
39	ARMA POWER TRANSFER (INTERNAL-EXTERNAL, OVER VOLTAGE)		61
40	ARMA POWER TRANSPER (EXTERNAL-INTERNAL, NOMINAL VOLTAGE)		6 2
41	ARMA POWER TRANSFER (INTERNAL-EXTERNAL, HOMINAL VOLTAGE)		63
ديدك	ARMA POWER TRANSFER (EXTERNAL-INTERNAL, UNDER VOLTAGE)		64
43	ARMA POWER TRANSFER (INTERNAL-EXTERNAL, INDER VOLTAGE)		65



REPORT 7B 2124-1

23

11 August 1959



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REPORT 7E 2124-1

PAGE 24

11 August 1959

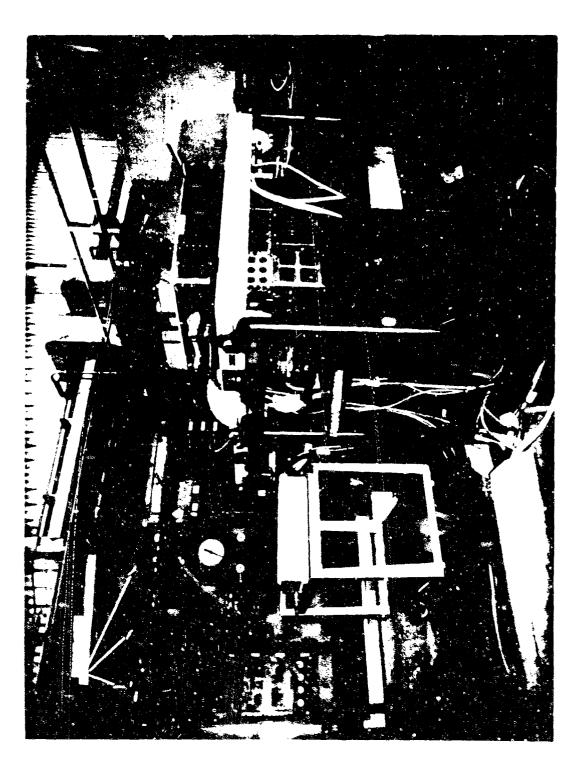


FIGURE 1

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#EPORT 7B 2124-1

PAGE 25

11 August 1959

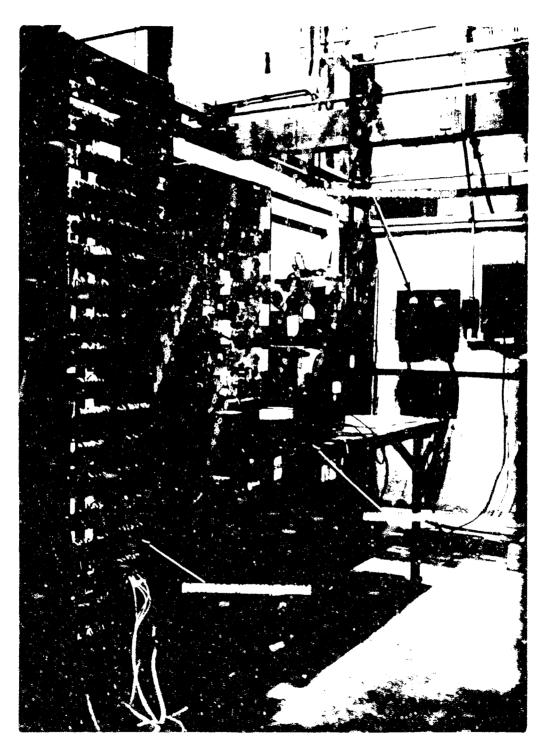


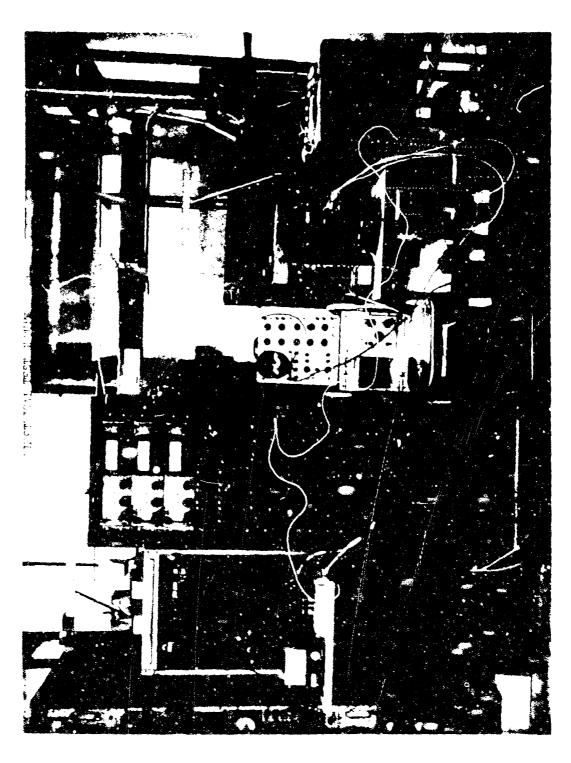
FIGURE 3

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PAGE 26

11 August 1959



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REPORT 7B 2124-1

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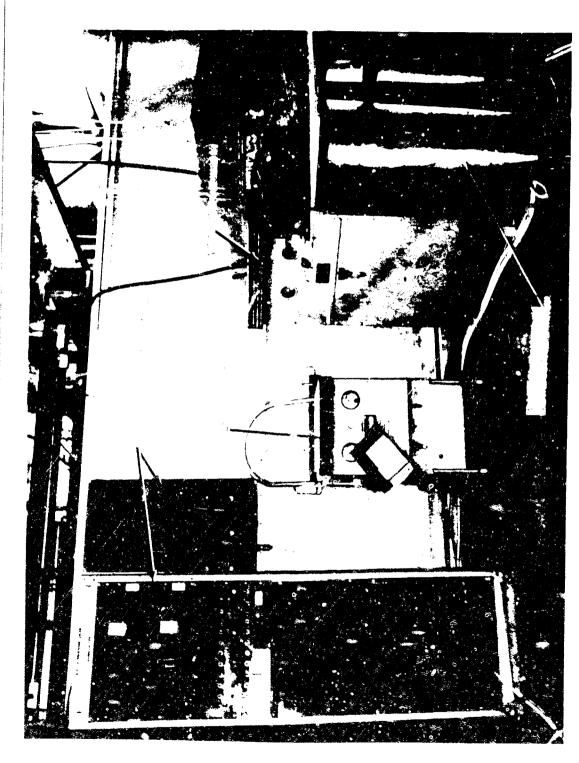


FIGURE 6

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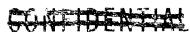
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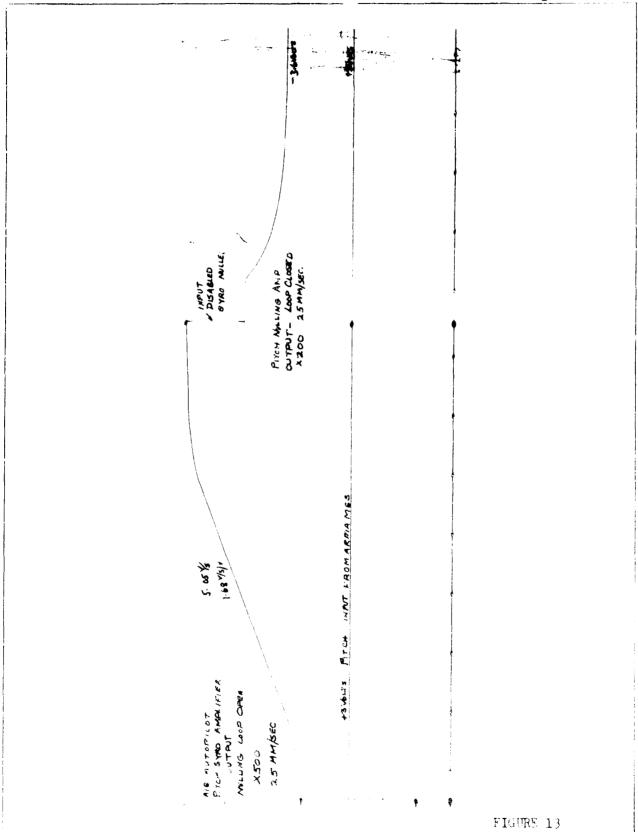


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REPORT 7B 2124-1
PAGE 35

11 August 1959



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PAGE 36

11 August 1959

FIGURE 14

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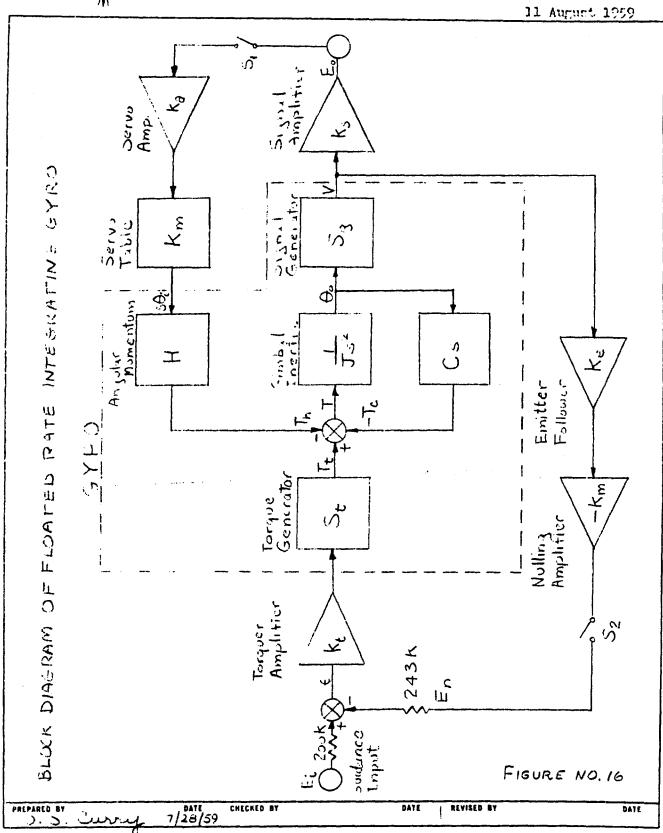
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TABLE COCILLARMS YAW CLOSED LOOP TAXING TEST USING CONTROL PRIMEWERS TABLE SANANA STAY AC. SHOW SPILLY - Y TIVIT SMES GUIDANCE BRINGLAD --YAW RATE GYRO DUTPUT & TABLE COST CLATAGE ARMA YAW STEERING INPUT SWONKE DISMED

FIGURE 15

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+1.0 0.428 +1.0 0.410 1.2 1.0 1.44 0.412 +0.5 0.216 +0.5 0.205 0.6 0.5 0.72 0.205 -0.5 0.215 -0.5 0.210 0.63 0.525 0.73 0.208 -1.0 0.430 -1.0 0.411 1.2 1.0 1.5 0.428 -2.0 0.855 -2.0 0.832 2.3 1.92 2.95 0.842 -3.0 1.310 -3.0 1.19 3.5 2.92 4.25 1.210		45.0	0.854	+2.0	0.820	2.3	1.92		0.86	788.7
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-3.0 1.310 -3.0 1.19 3.5 2.92 4.25 1.210		7	0.865	6.0	0.832	2.3	1.92		0.872	1.32%
FIGURE 17		<u></u>	1.310	-3.0	1.19	3.5	2.92		1.210	1.68%
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7B 2124-1 PAGE 40

11 August 1959

Ž-FIGURE 18

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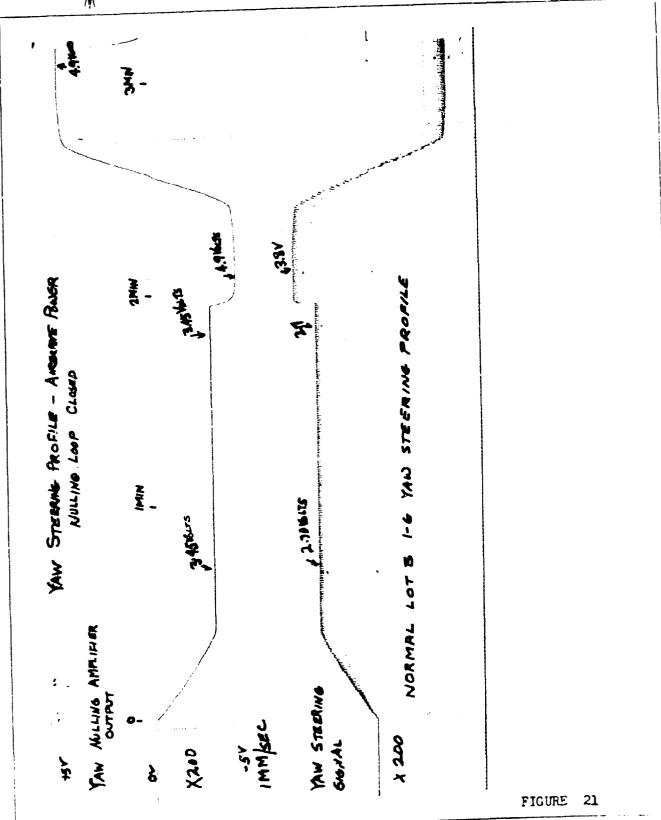
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43

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FIG URE

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11 August 1959

CYRO NULLING CLOP CLOSED (LUO E IDANCE SIGNAL) TO AIR BOOMS POWER FROM GROUND POWER CHANGE - OVER POWLA CHANGLOVER TIMING RECERENCE 25MM/502 FIGURE 23

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REPORT 78 2124-1

PAGE 46

11 August 1959

GYAD NULLING LOOP OPEN ; GUIDAMER DISABLES POWER CHANGE-OVER FROM GROUND TO AIRBORNE POWER TIMING PEFERENTER SACONO POWER X FIGURE 24

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<u>W</u>	11 August 195
FROM GROUND TO AIRBORNE FOWER OPE 15 GUIDANCE ENABLED SLOVE X 20 25	CHANGE OVER
CHANSE-OVER NULLING LOOP CHANKE-OVER	in interested
TIMING REFERENCE TIMING REFERENCE SEMMO RABER 25 MM/SEC	00 7 P U 7 A 20 A

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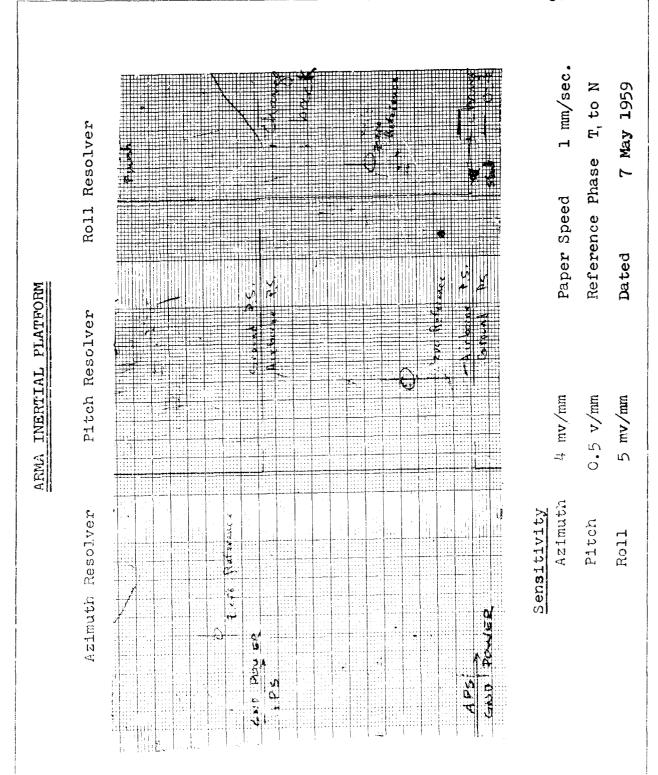
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11 August 1959



FIGURY 26

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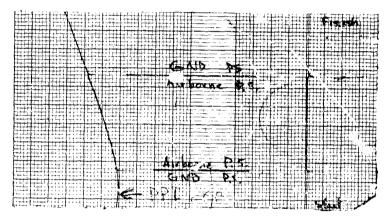
PAGE 49

11 August 1959

ARMA INERTIAL PLATFORM

Pitch Pendulum

Roll Pendulum



Pendulum Gradient

20 sec/mv

Sensitivity

1 mv/mm

Paper Speed

1 mm/sec.

Reference Phase

A So B

Earth Rotation Component

about Y axis

8 degrees/hour

PPI Torquing Amplifier Off

FIGURE 27

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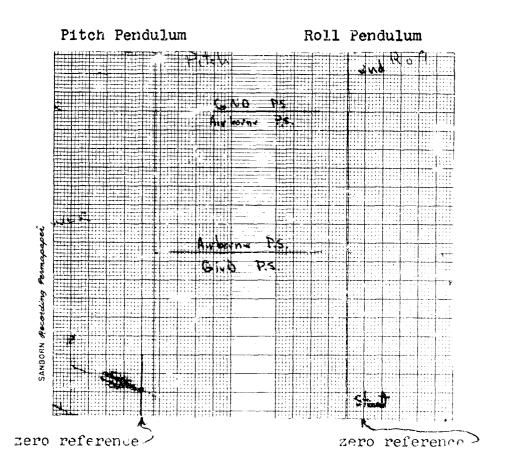
ASTRONAUTICS

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ARMA INERTIAL PLATFORM



Pendulum Gradient

20 sec/mv

Sensitivity

1 mv/mm

Paper Speed

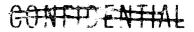
1 mm/sec

Reference Phase

A to B

FIGURE 28

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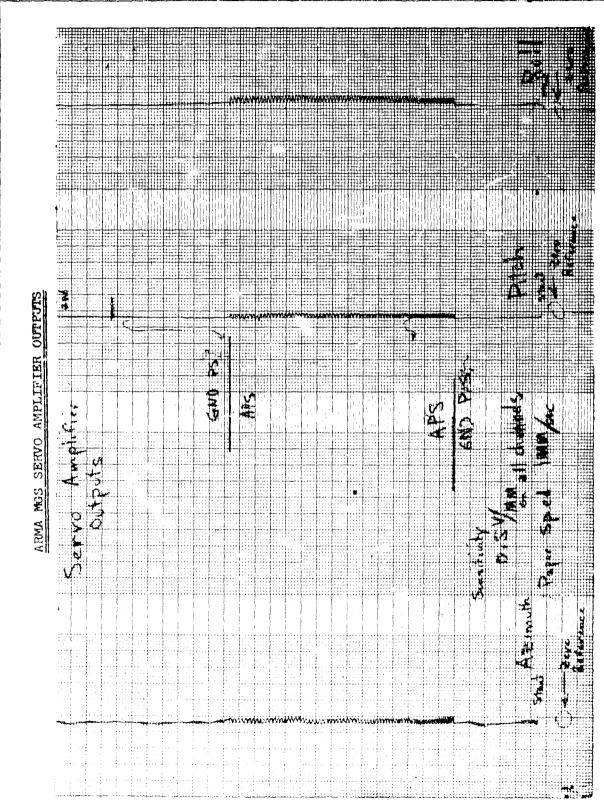


FIGURE 29

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REPORT 7B 2124-1 PAGE 52 11 August 1959

MOTHE 30

COMPUTER POWER SUPPLY VOLTAGES

Nominal Voltage	OUTPUT - DC VOLTAGE	GROUND P.S. AC VOLTAGE	OUIPUT - DC VOLTAGE	AIRBORNE P.S. AC VOLTAGE
-50	-49.0	0.3	-49.0	0,7
-16.5	-15.8	0.2	-15.8	0,19
-10	-10,1	0,16	-10.4	റ.28
+3.3	+ 3.1	0.12	+ 3.1	1.5
+4	÷ 3.9	9.19	8.5 +	0.3
+38	+39.5	0.3	+39	0.36
+28	+28	0.27	+28	0.3

LINE VOLTAGE	GROUND POWER SUPPLI	AIRBORNE POWER SUPPLY
Phase T ₁ - N	115	114.8
Phase T ₂ - N	117	116.3
Phase T ₃ - N	116.6	116.2

CONTROL DC VOLTAGES

	XXXXXX			
NOHINAL	OUTPUT DC VOLTS	- GMD PS AC VOLTS	QUTPU DC VOLTS	
Gyro Magnet Supply 4.5VDC 8V10	′ .0	8.7	4.2	8.8
Gyro Torquer Voltage 3.5VDC, 3.5VDC	3.8	0.16	3.7	0.16
Preamplifier Voltage -22.5VDC	-22	0.16	- 22	0.16
Accelerometer Supply	22	5 HV	- 22	5 :K V
Amplifier Output Suppl	y 23	11.4	23	11.2
LINE VOLTAGE	GROUND	POWER SUFFLY	AIRBORNE	POWER SUPPLY
Phase T ₁ - N Phase T ₂ - N Phase T ₃ - N	1	16.3 17.4 17.4	11	4.9 6.2 6.1

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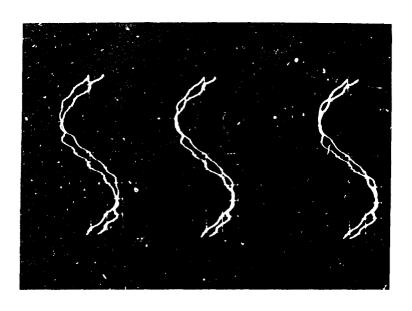
*	EUH			PHASE A		-		P!'ASI	Е В		
	INVERTER		v	I	น	P.F.		v	1	W	P.F.
		BFFORE AFTER	115.6	5.8 5.75	600 590	0.896		116.3	4.84	500 500	0.889
	ARM		114.5	3.8	420	0.966		115.6	3.6	400	0.96
	ATTO	<u>:</u> !	115.0	1.115	90	0.703	•	115.9	0.813	37.5	0.399
	i Sprulatei		114.5	0.84	82.5	0.86	•	115.4	0.735	72.5	0.855
	TOTAL:		115	5.51	592.5	0.92	<u>:</u>	115	4.75	510.0	0.894
	יינים: יונים: מיינים: יונים: מ										
	nverter	BEFORE AFTER	114.0 113.4	5.92 5.90	615 610	0.911	1	115.1	4.55	470 465	0.897
1	A FOMA		113.1	3.72	404	0.96	-	114.4	3.55	374	0.92
• • • •	PHOT		113.4	1.33	123.5	0.818		115.0	0.195	15.5	c.692
,	STULATE		115.4	0.83	81	0.845		114.4	0.735	71.5	0.851
	TOTAL:		115	5.74	608.5	0.924	· · · · · · · ·	115	4.44	461.0	0.904
·		SYSTI	I LOAD W	iti: Simil	TFD LOAD	DUMPED					
	INVERTER		114.5	4.8	511	0.93		115.0	3.86	420	0.945
***	~	 			,	-					
	1		-								
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!				PH	ASE C		TOTAL 3 PHASE WATTS	E	en meneral de la serie de la compansión de	•••••••••••••••••••••••••••••••••••••••	and the second second second	
	P.F. 0.889 0.92		v 115.9 114.6	5.72 5.65	555 540	P.F. 0.837 0.836	WATTS 1655 1630	VT ₁ -T ₂ 200.4	VT3-T3 200.7	YT3-T1 200.4	Vde 27.9	Ide 116
	0.96		115.1	3.8	390	0,892	1210					
	0.399		115.0	1.375	47.5	0.302	175				-	
٠	0.855		114.9	1.175	106	0.785	261					
	0.894		115	6.05	543.5	0.784	1646	•	· ·	4		1
	0.897		114.6 114.0	5.82	550 545	0.825	1635 1620	200.8	201.4	200.9	27.8 27.8	126
	0.92		113.8	3.85	380	0.870	1158		•			
•	0.692	•	114.2	0.€32 ↓	40	0.554	179		•			•
	0.851		113.8	1.163	104.5	0.790	257			· · · · · · · · · · · · · · · · · · ·		•
	0.904		115	5.5	524.5	0.825	1594		**************************************			
	0.945		115	4.4	440	0.87	1371	198	199	198.9	27.9	100
				NOTES:	2. Mans	ured Volt ured Curr ured Watt	ents are	+2%				-
												• • • • • • • • • • • • • • • • • • •
1	•			• • • • • • • • • • • • • • • • • • •					FIGURE 3	þ	\rangle \(\frac{1}{2} \))

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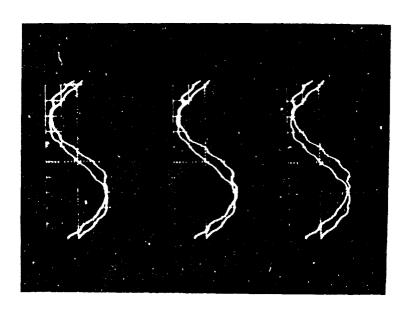
11 August 1959



TOTAL SYSTEM LOAD

WAVE FORKS

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SIMULATED LOAD OFF

FIGURE

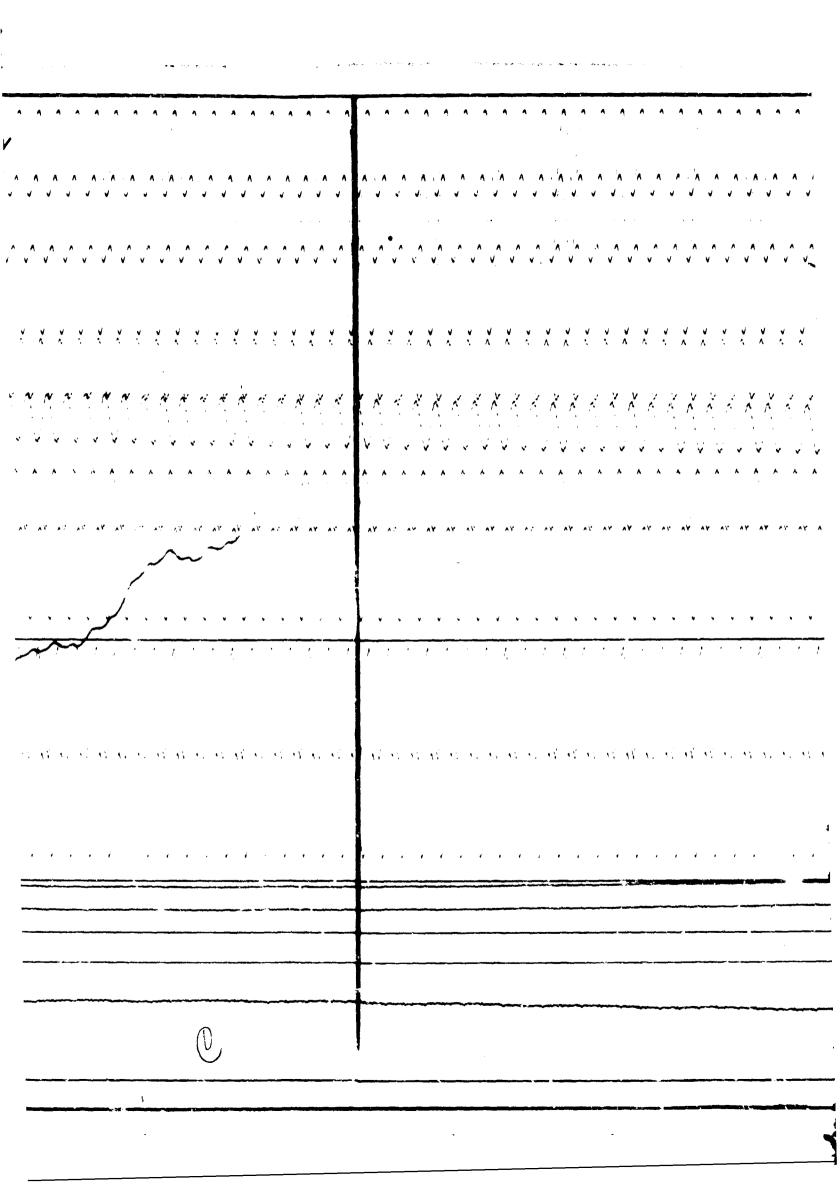
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		400	800	1200	16 00	2000	2400	2800	3 200	3600	4000	4400	
	Ì	,	RUI HO.	1 DIVERT	R VOLTAG	E - R.M.S	VALUES						
F "	Λ	110	0.34	0.38	0.20	0.50	0.16	2.50	0.27	0.48	0.35	2.50] -
An a Seems of the Co.	B	107	0.30	0.60	0.23	0.63	0.06	2.0	0.24	0.54	0.30	2.0	1
	C	109	0.26	0.22	0.20	0.60	0.0	1.9	0.35	0.04	0.36	3.0	
••		- ,	RUT HO.	2 INVERT	R VOLTAG	E		i					
•	A	194	0.28	0.37	1	0.58		2.15		0.30		2.7	
	B	105	0.25	0.50	!	0.67		1.85	1	0.33		2.39	
	C	104	0.24	0.22		0.72		1.75		0.10		2.80	
			RUE HO.	1 INVERT	R CURREL	r - R.M.S	, VALUES		1				
	¥	5 .7 0	0.14	. ∪.33	0.072	0.054	0.024	0.16	0.01	0.044	0.038	0.088	1
	\mathbb{D}	4.34	0.12	0.26	0.072	0.04	0.004	0.136	0.012	0.03	0.008	0.18	1
	C	4.72	0.114	0.21	0.046	0.08	0.024	0.096	0.008	0.028	0.024	0.23	
			RUN NO.	2 IIVERT	ER CURRET	Ţ	,						
	jk	5.40	0.136	0.30	1	0.072	i •	0,068		0.036		0.116	
	12)	4.00	0,12	0.48	:	0.03	1	0.124		0.016		0,208	
4	C	5.20	0.108	0,20	•	0.078		0.116		0.024		0.23	
•	}		RUI NO.	1 IIVERT	TR VOLTAG	E - % of	FULL AMERICA	AL (R.M.	s.)				
	A	100	0.31	0.346	0.182	0.455	0.145	2.27	0.246	0.437	0.318	2.27	C
	В	100	0.28	0.56	0.215	0.589	0,056	1.87	0.224	0,505	0,28	1.57	C
,	C	100	0.238	0.202	0.184	0.55	0	1.745	0.321	0.037	0.33	2.75	C
		ļ	RY NO.	2 L'VERT	R VOLTAG	Ė							
	Α	100	0.269	0 .3 56	1	0.558		2.065		0.288		2.6	
	В	100	0.248	0.276		0,638		1.905		0,314		2,28	
1 44	c	100	0,230	0.212	1	0,692		1.68		0,096		2,69	
			RUL NO.	1 INVERT	R CURREN	7 - 5 of	TUENAL'EUT	AL (R.H.	3.)				
	A	100	2.46	5.8	1.26	0.948	0.421	2.81	0.175	0,773	0.676	1.54	0
	15	100	2.76	6.0	1.66	0.92	υ .09 2	3.13	0.275	0.69	0.184	4.14	0
	C	100	2.42	4.45	1.03	1.69	0.508	2.03	0.169	0.593	0.508	4.87	1 +
****			RUN NO.	2 IIVERT	R CURREN	İ.,	L						
	î.	100	2.52	5.56		1.33	1 !	1.26	0.666		2.15		,
	\mathbb{B}	100	3,00	12.0		0.75		3.1	0,4		5.2		
	C	100	2.57	5.76		1.86		2.76	0.571		5.48		
	,				- VOLTAG	E R.M.S.							
	H	Jy 110. j	1 [:	$\sum_{10}^{2} v^2$	1 12		20 v ²	b	[2	$-\frac{20}{2}$ $\sqrt{2}$	<u> </u>		+
	: A		V fundame	•	0.025 V	Ĭ	1		0.035V F	ind.			! i
Λ	3		V Fund.		0.023 V				0.031V F	!			
$l\lambda$	C		V Fund.		0.030 V	1			0.035V F	1			
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n .	12	13	14	15	16	17	1.18	19	20	R.M.S.	TOTAL
400	4800	5200	5600	6000	6400	6800	7200	7600	8000	SUM	VALUE
							ļ				peters
.50	0.09) .68	0.20	0,22	0.13	0.50	0.20	0.48	0.23	110.07	115.6/
.0	0.2	0.53	0.28	0.18	0.11	0,50	0.28	0.78	0,24	107.05	<i>₹₹∫′′</i>
3.0	0.14	1.00	0.04	0.12	0.09	0,60	0.07	0,40	0.05	109.07	116.37
2.7		e communication						··· -		201.06	1
Į										104.06	113.4/
2. 3 9					· · · · · · ·					105.05	1117.4
2.80										104.06	113
0.088	0.02	0.088	0.01	0.01	0.006	0.006	0.004	0.028	0.002	5.70	6.12/
.18	0.02	0.092	0.016	0.016	0.006	0.044	0.006	0.040	0.004	4.37	4.25/
23	0	0.064	0.004	0.008	0.004	0.024	0.004	0.018	0.002	4.74	6.0/
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23			t I	<u> </u>	i	!		-		5.21	,5:3/-
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.27	0.082	0.619	0,182	0.20	0.118	0.455	0.182	0.436	0,209	T .	105/
.47	0.187	0.495	0.261	0.168	0.103	0.467	0.262	0.73	0.224		109706
2.75	0.128	0.92	0.037	0.110	0.083	0.55	0.064	0.367	0.046		106.67
									-		109/100
2.6						†					
2.28			· · · · · · · · · · · · · · · · · · ·	 		-		†			109/
.69											109.5
				· · · · · · · · · · · · · · · · · ·	<u>.</u>						107.2/
.54	0,351	1.54	0.175	0,175	0.105	0.105	0.07	0.492	.0351	-	1,03
.14	0.46	2,12	0.368	0.368	0.138	1.01	0.138	0.92	0.092		107.2/ 103. 127/12
• <u>87</u>	٠ ن	1.36	0.085	0,269	0.085	0.518	0.085	0.361	0.042		14,714.
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GA VOLTS // / / / / / / / / / / / / / / / / /		EXTERNAL
DE VOLTS # * * * * * * * * * * * * * * * * * *		
GC VOLTS # * * * * * * * * * * * * * * * * * *	a .	
GC AMPS JOURNALINGS JOURNALIN		
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V _{T1} -T _B V _{T2} -T ₅ V _{T3} -T ₇ MVERTER BC.VOLTS		
V _{T1} -T _B V _{T2} -T ₃ V _{T3} -T ₇ ARMA-AUTORILOT DC. VOLTS MVERTER DC. VOLTS	* * * * * * * * * * * * * * * * * * *	
V _{T1} -T _B V _{T2} -T ₅ V _{T3} -T ₇ MVERTER BC.VOLTS	INVERTER ØA VOLTS //	76.2 V
VT3-T7 ARMA-AUTOPILOT DC. VOLTS NVERTER DC. VOLTS		
VT3-T7 ARMA-AUTOPILOT DC. VOLTS NVERTER DC. VOLTS	10	OAULISECANDS
VT3-T7 ARMA-AUTOPILOT DC. VOLTS NVERTER DC. VOLTS		
ARMA-SUTAPLLOT DC. VOLTS INVERTER DC. VOLTS	V _{ri-Ta}	
ARMA- NUTOPILOT DC. VOLTS INVERTER DC. VOLTS	V+2-+3, 44 44 44 44 44 44 44 44 44 44 44 44 44	TAN AN
ARMA-SUTOPILOT DC. VOLTS INVERTER DC. VOLTS	V ₇₃ -7,	•
INVERTER DC. VOLTS	* * * * * * * * * * * * * * * * * * * *	
INVERTER DC. VOLTS		
INVERTER DC. VOLTS		
	ARMA-SUPPLIEDT DC. VOLTS	
INVERTER AMPS		INVERTER DC. VOLTS
FIG	INV	ERTER AMPS
		FIG

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ØA VOLTS

ØB VOLTS

BB AMPS 4.1A

C AMPS 5.5A

INVERTER GA VOLTS //3.6 V

 $V_{\pmb{\tau}_1 - \pmb{\tau}_{\pmb{z}}}$

V---

VTB-T,

INVERTER AMPS

INVERTER AMPS

FIGURE 36

//2.2 V D. C. VOLTS

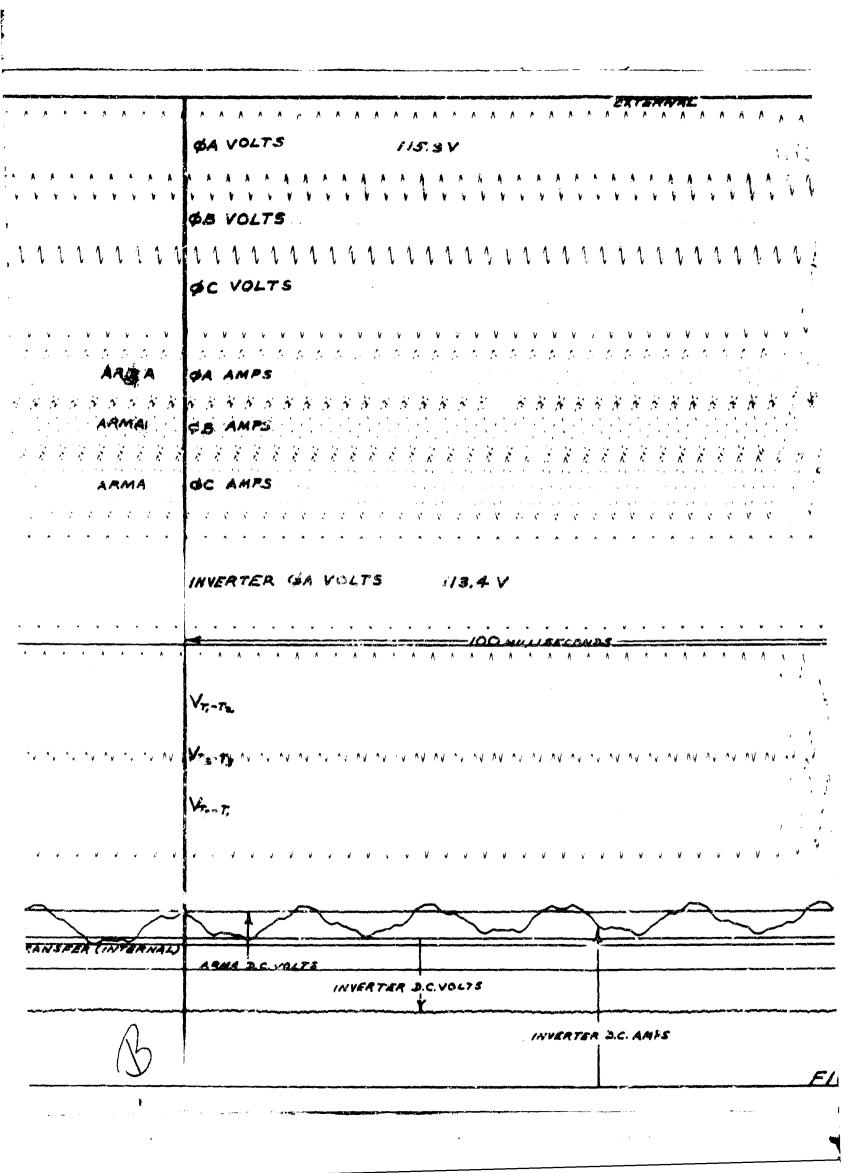
112.2 V

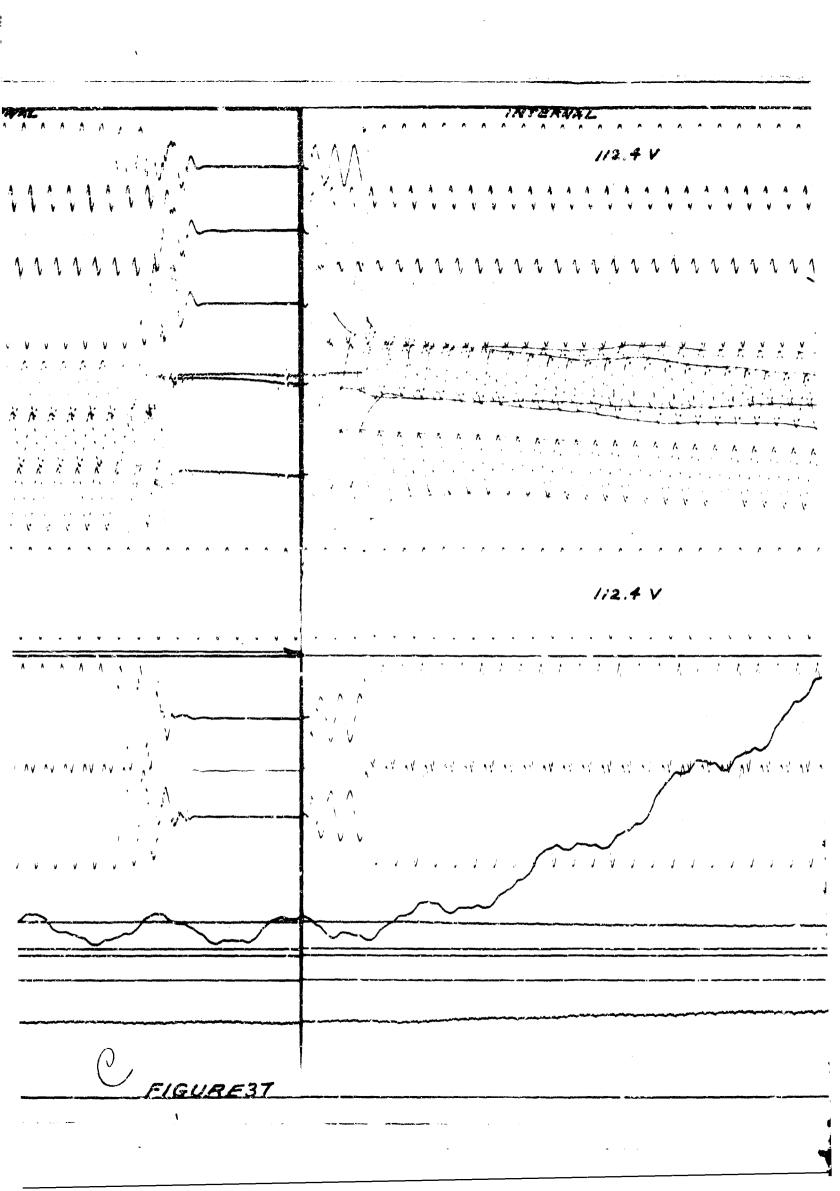
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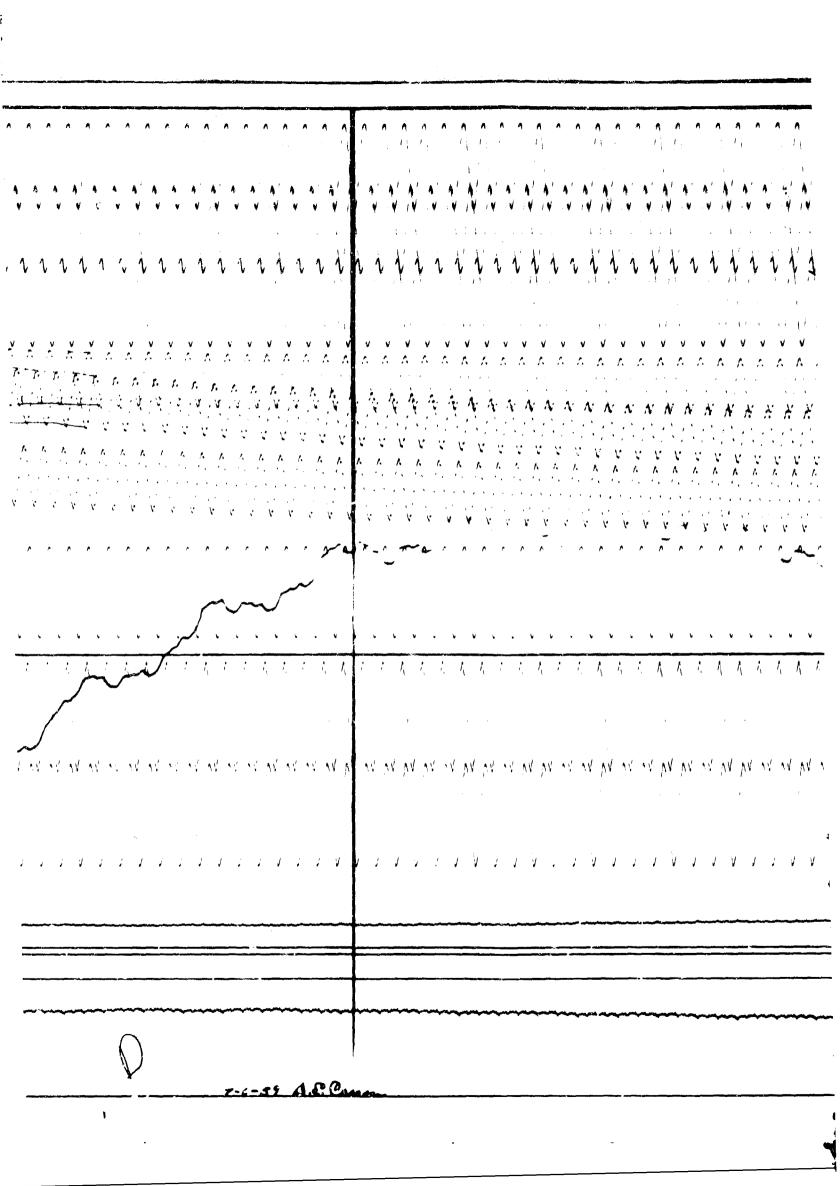
112.2 V

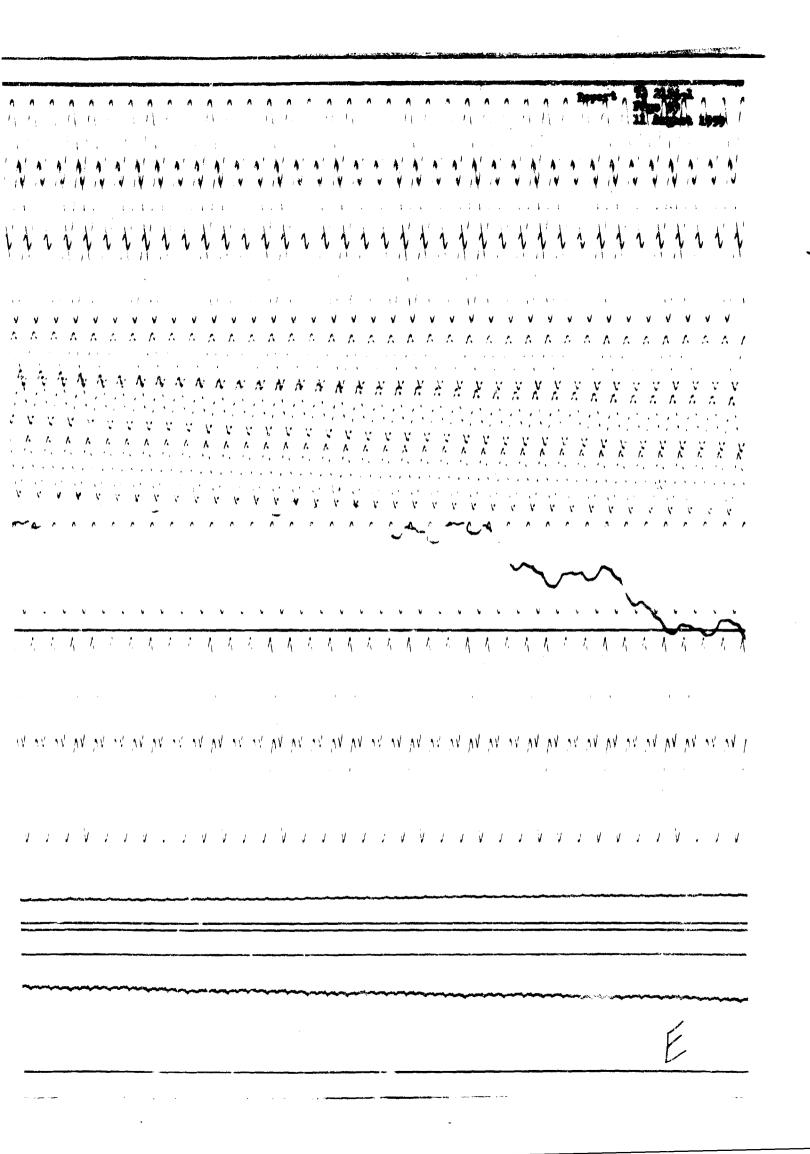
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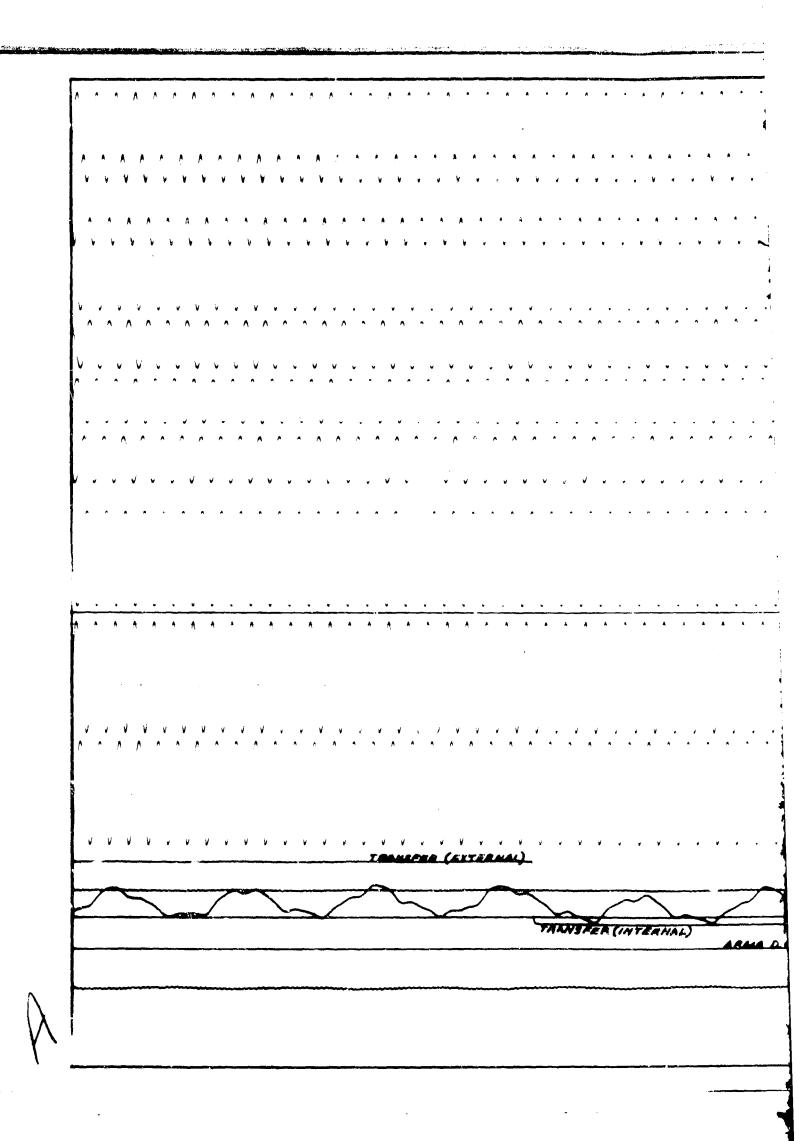
\ ^	r / /		A V V	Λ Λ :	* ^ Å	, A	Λ Λ	* A A	A A	٨	• •	A A	. ,	^ ^	^ ^
A A A	^ ^ ^	A A A	A A	A A A	A A A	A A	д . « V . V	^ A	A A	A A V V	A A	, , , , , , , , , , , , , , , , , , ,	A .	A A *	
111	\ \ \ \	11	111	111	1 1	111	. 1 1	1 1	1 1	1 1	; 1	. 1	1 1	1 1	113
b v v 1	v v v :	V V V	V V V 	/ V V	· · · · ·	,	V V 5 5	v v :		v v : .:		v v 4 4	•	(. v v ∴ ∴
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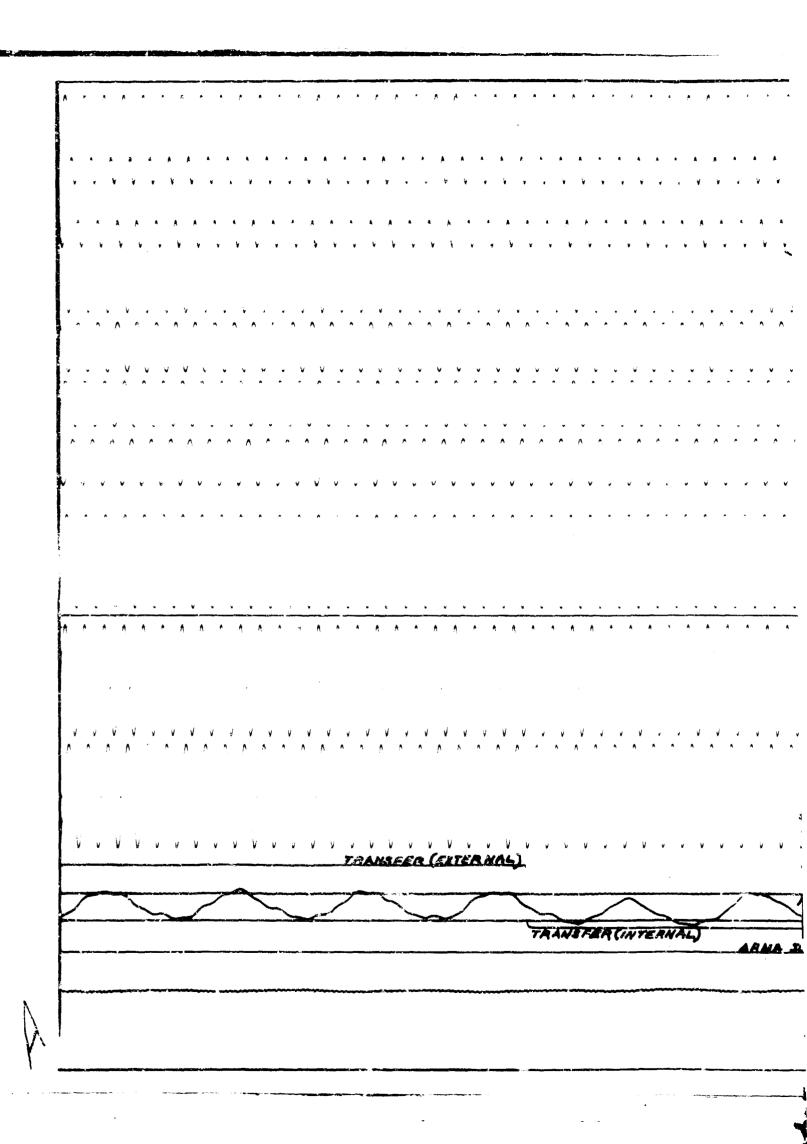
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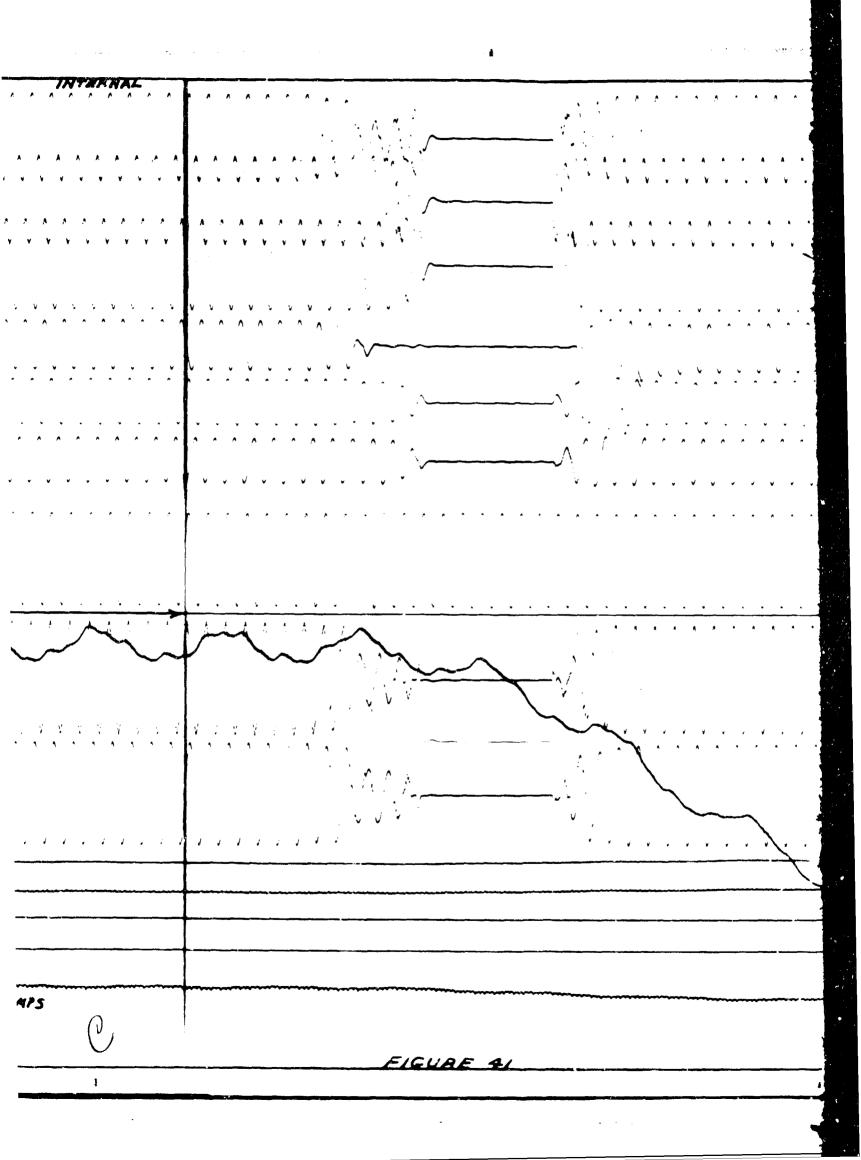
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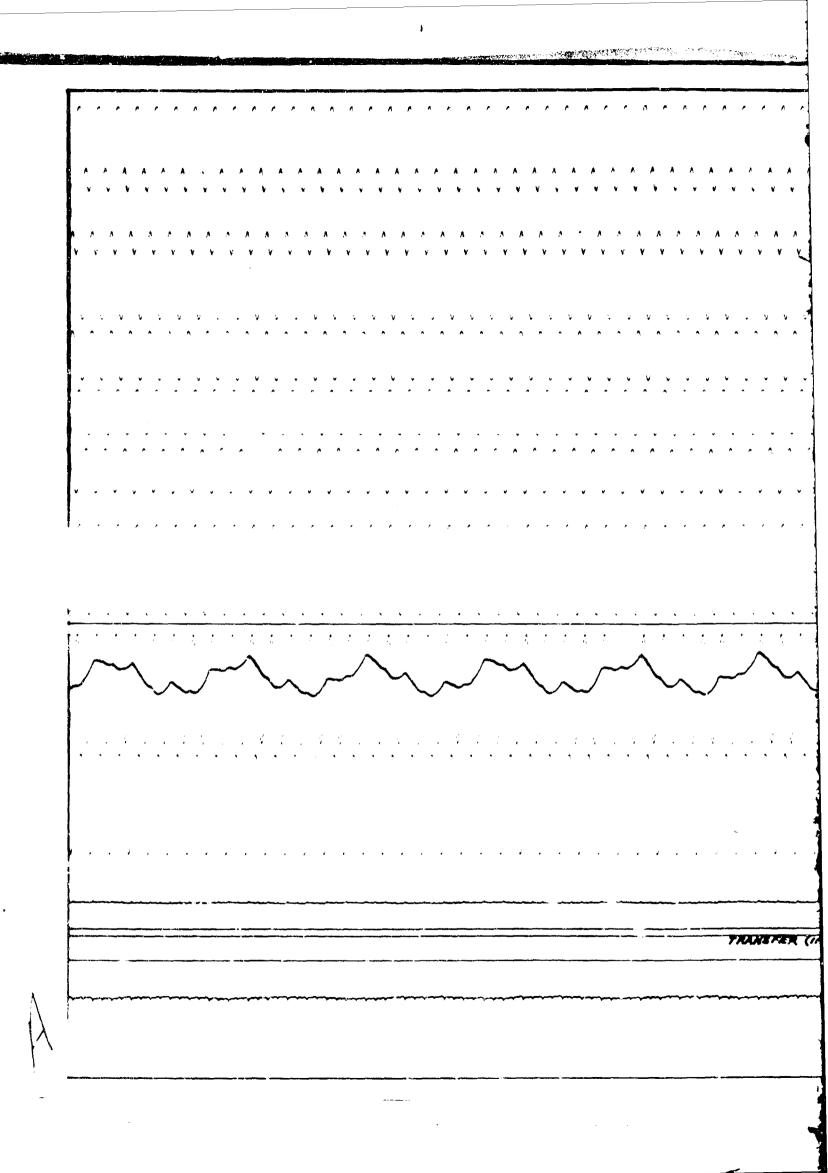
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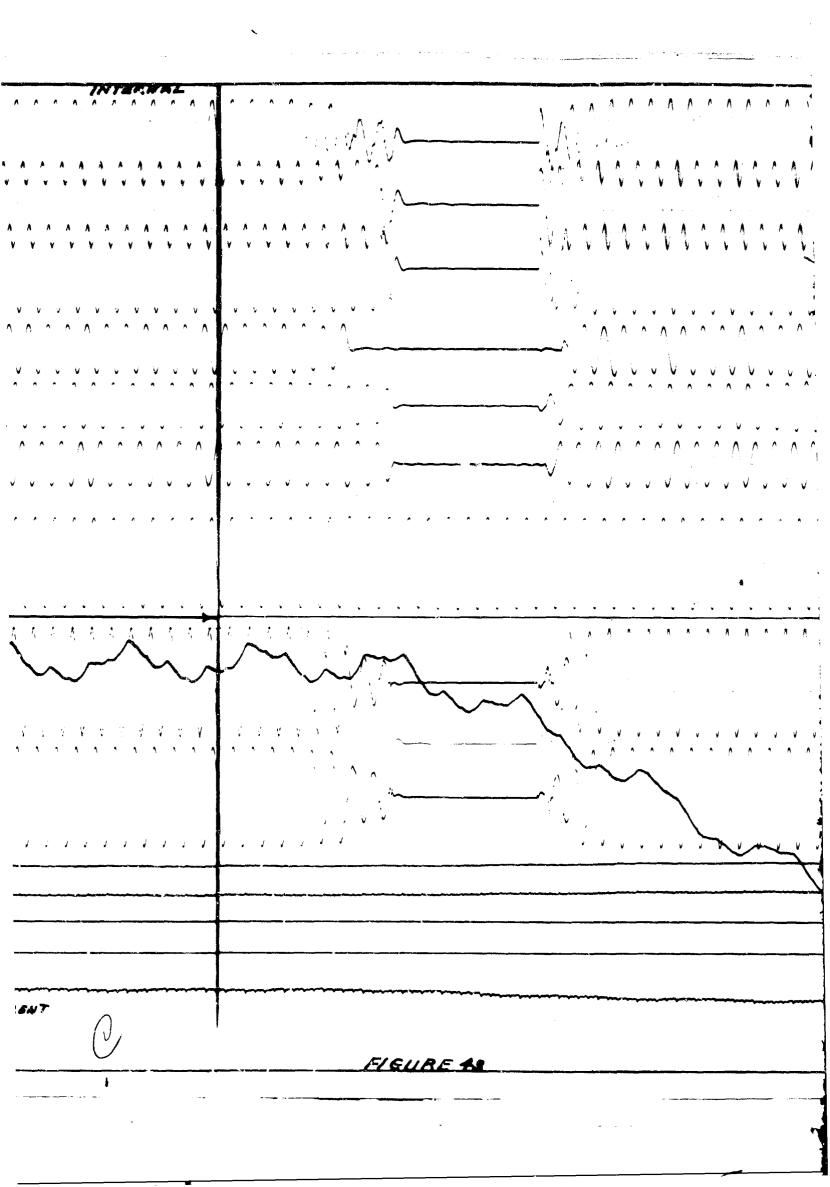
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